ACHIEVING AERONAUTICS LEADERSHIP

Aeronautics Strategic Enterprise Plan

1995-2000 - April, 1995

A MESSAGE FROM THE ENTERPRISE SENIOR MANAGEMENT

"Anyone can steer the ship when the sea is calm."

Publilius Syrus

The seas in which we find ourselves today are anything but calm. The global context, with the end of the Cold War, simultaneous multinational partnerships and foreign competition in the airline and aviation manufacturing industries, and continued growth in air travel with its associated challenges, is one of constant change. At home, industry and defense downsizing -- coupled with a highly constrained budgetary environment and the need to reinvent government -- is forcing a reexamination of a successful eighty-year government, industry and academic partnership in aeronautics.

Today, more than ever, aggressive leadership is required to ensure that our national investments in aeronautical research, technology, and facilities are shaped into a coordinated, and high-impact, strategy. Under the auspices of the National Science and Technology Council, and in conjunction with the domestic industry, universities, the Department of Defense, and the Federal Aviation Administration -- our partners in aeronautics -- we propose to provide that leadership, and this document is our plan.

For us, national leadership means stepping up to a more prominent role in determining our national aeronautical priorities and investments. It means being a strong player in the national partnership: delivering on our commitments, seeking cost-effective and innovative ways to do business, and focusing on high-risk, high-payoff research. And it means ensuring that the benefits of our national investments in aeronautics are shared by all segments of our diverse society.

We are not there yet, and there is much work to do. On behalf of the thousands of men and women who comprise NASA's Aeronautics Enterprise, we present this plan as our roadmap to the future -- to achieving aeronautics leadership.

Signed by:

Robert E. Whitehead, Acting Associate Administrator, Office of Aeronautics - 3/21/95

Ken K. Munechika, Director, Ames Research Center - 3/27/95

Paul F. Holloway, Director, Langley Research Center - 3/23/95

Kenneth J. Szalai, Director, Dryden Flight Research Center - 3/23/95

Donald J. Campbell, Director, Lewis Research Center - 3/24/96

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I. EXECUTIVE SUMMARY

The National Aeronautics and Space Act of 1958, NASA's founding legislation, calls for the agency to:

- Improve the usefulness, performance, speed, safety, and efficiency of aeronautical vehicles;

- Establish long-range studies of the potential benefits to be gained from, the opportunities for, and the problems involved in the utilization of aeronautical activities for peaceful and scientific purposes; and

- Preserve the role of the United States as a leader in aeronautical science and technology and in the application thereof.

To carry out that charter, the Aeronautics Enterprise has defined the following mission:

> "To be the world leader in pioneering high-payoff, critical technologies with effective transfer of research and technology products to industry, the Department of Defense, and the Federal Aviation Administration for application to safe, superior, and environmentally-friendly U.S. civil and military aircraft, and for a safe and efficient National Aviation System.
>
> We will aggressively pursue the identification, development, verification, transfer, application, and commercialization of aeronautics technologies to stimulate economic growth and to enhance U.S. competitiveness and world leadership in both aerospace and non-aerospace industries. In addition, we will ensure the continuing excellence of U.S. aeronautics for future generations by fostering and supporting multi-disciplinary education in elementary, secondary, and higher institutions of learning.
>
> NASA carries out its aeronautics mission in partnership with the Federal Aviation Administration, the Department of Defense, industry, and academia. Our primary role lies in basic and applied research and technology development. In addition, through the operation of national aeronautical facilities, NASA is involved -- in close cooperation with industry, DOD, and FAA -- throughout the development process."

Dynamic change is buffeting all of the Enterprise's customers. Advanced technology development and application will be required to ensure our nation's economic and national security in the next century. Domestic engine and airframe manufacturers, from general aviation aircraft to large commercial transports to military aircraft and civil tiltrotors, will require access to high-risk, high-payoff research and technology efforts to address product cost, quality, and reliability, as well as the need for shortened product development cycles. Removing the "barriers to growth" represented by capacity and environmental constraints in the air transportation system will also require new technology. The U.S. air traffic system must keep pace with anticipated demand, and U.S. products equipped to operate in underdeveloped airspaces will enjoy a significant competitive advantage.

To address these challenges, the Aeronautics Enterprise will aim for -- and achieve -- a national leadership position in the planning and conduct of the nation's aeronautical research and technology effort. This strategy has three basic components:

- Shared leadership in determining national priorities and investments;

- Being a key contributor to the national government/industry/academic partnership; and

- Ensuring that aeronautics benefits all Americans.

Programmatically, the Enterprise will:

- Develop high-payoff technologies for a new generation of environmentally compatible, economic U.S. subsonic aircraft and a safe, highly productive global air transportation system;

- Ready the technology base for an economically viable and environmentally friendly high speed civil transport;

- Ready the technology options for new capabilities in high performance aircraft;

- Develop and demonstrate technologies for airbreathing hypersonic flight;

- Develop advanced concepts, physical understanding, and theoretical, experimental, and computational tools to enable advanced aerospace systems; and

- Develop, maintain, and operate critical national facilities for aeronautical research and for support of industry, the FAA, DOD, and other NASA programs.

In addition, future investments are anticipated in affordable design and manufacturing technologies, information systems technologies, national research facilities, and air transportation system technologies. In implementing these programmatic activities, the Enterprise will act in accordance with the following principles:

- Ensure relevance to customers and responsiveness to our stakeholders;

- Maintain a balanced program;

- Make the university community a full partner;

- Exercise responsible stewardship of national facilities;

- Utilize strategic alliances;

- Emphasize commitment to people;

- Increase measurement and accountability;

- Emphasize technology transfer; and

- Pursue synergy with other NASA Enterprises.

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II. A ROADMAP FOR THE FUTURE: AVIATION IN 2020

NASA's Aeronautics Enterprise is in the research and technology business. The very nature of that business -- one where the benefits of today's "products" and efforts may not be realized for several years, or even decades -- places a premium on being able to take a longer-term view. Working with suppliers, customers, and stakeholders, the Enterprise has developed a vision of aeronautics in the year 2020 -- national capabilities that will be required for the United States to maintain its leadership in aeronautics and air transportation. This vision helps guide the development and execution of our aeronautics research and technology program.

National Transportation Vision

To begin, we recognize that aviation is but one facet of a highly-interactive national passenger and cargo transportation system. In order to make the best possible investment decisions on behalf of our ultimate stakeholder and customer -- the American citizen -- it is critical that we understand the relative importance and benefits of various transportation investments.

Toward that end, the Enterprise has worked closely with the National Science and Technology Council's Interagency Coordinating Committee on Transportation Research and Development (CTRD). In their recent report on transportation research and development priorities, the Committee defined the following vision for a national transportation system:

The Committee's vision is of a sustainable and seamless intermodal transportation system that effectively ties America together and links it to the world. This system will help citizens and businesses satisfy their needs by providing efficient, safe, secure, and environmentally-friendly transportation of people and goods. It will result from a strengthened partnership between government and the private sector focused on effective management and renewal of existing infrastructure, strategic deployment of new technologies and infrastructure, and on R&D which supports each of these.

The Aeronautics Enterprise's vision of the future -- and its programmatic activities -- are grounded in that total transportation systems context.

Aviation in 2020

In today's dynamic environment, making predictions about 25 years into the future carries with it some risk. However, the aviation world of 2020 is likely to be characterized by:

- **Increased Numbers of Both Old and New Types of Aircraft.** Large commercial airline inventories will increase by over 50 percent, and the regional/commuter fleet will more than double from today's levels. In addition, the fleet will include new types of aircraft, potentially including:

    - Superjumbo subsonic commercial transports, capable of carrying greater than 600 passengers or equivalent cargo loads.

    - Second-generation high-speed (i.e., supersonic) transport aircraft, perhaps capable of quiet, supersonic over-land flight;

    - A mix of sophisticated fanjet, propjet, and turboprop commuter and general aviation aircraft;

    - Advanced helicopters and new tiltrotor/tiltwing aircraft ferrying passengers from city center to city center;

    - Hypersonic research vehicles, leading to hydrocarbon-fueled, atmospheric cruise vehicles for military and/or commercial cargo applications; hydrogen-fueled Mach 10 waverider vehicles for military reconnaissance and/or deep strike operations; and remotely-piloted, over-water Mach 5-6 hypersonic vehicles used for overnight package delivery services; and

    - Highly-stealthy, highly-maneuverable military aircraft with enhanced survivability characteristics.

- **Increased Applications of Advanced Aircraft Technologies.** These new aircraft will employ a variety of new technologies to meet customer requirements for reduced acquisition costs, lower operating costs, increased safety and environmental compatibility, and improved maintainability. For example:

- Technologies to reduce the environmental impacts of noise and engine combustion products. Commercial airliners in 2020 will be "quiet" aircraft, operating near ambient (i.e., background) noise levels, and will emit 50 percent fewer combustion by-products;

- Highly-blended wing-body configurations, such as the "all flying wing," to meet performance and low observability requirements.

- Technologies for "smart structures" and "smart surfaces." Health-monitoring systems in power plants and structures will enable the prediction of pending failures. Other systems will enable the real-time identification and characterization of problems with control systems and other flight parameters, as well as real-time system reconfiguration to enable continued operability; and

- Technologies for "all-electric" aircraft (i.e., replacing electrical and mechanical cables and hydraulics with fiber optics) and "all-plastic" aircraft (actually polymer matrix composite materials).

- More Flexible Design and Manufacturing. Advances in agile aircraft design, development, and manufacturing processes and technologies will be key to future affordability and product flexibility. For example, the next twenty-five years should see a 50 percent reduction in the time required to design and deliver a new commercial transport aircraft. A portion of these productivity gains will result from the increased use of sophisticated supercomputing and networking technologies that will enable "virtual aircraft design," the ability to simulate an entire aircraft via computational capabilities.

- Increased Applications of Information Science Technologies. New capabilities in information management -- the acquisition, integration, display, and utilization of data from the aircraft and the surrounding environment -- will change the way in which aircraft are operated. For example:

- Advanced sensors will provide data on wing-ice build-up, terrain and traffic proximity, adverse weather conditions, and other factors. Information from these sensors will be integrated into expert flight management systems that provide real-time data and options to pilots.

- Advances in display technology will also enable the more efficient use of such information. Cockpit systems will provide head-up displays, complete with 3-D visual and aural cues and featuring voice activation, to enable effective human - machine interaction and responses.

The next 25 years should also see the initial applications of exotic sensor technologies, for example the use of nanotechnologies as sensors to detect and adjust to increases in turbulent airflow. Information and sensor technologies will also play a role in ground-based operations. Virtual reality and synthetic vision technologies will be used in simulators for pilot training, as well as for simulating and designing manufacturing processes and maintenance routines.

- An Advanced Air Traffic Management System. Finally, significant advances in global air transportation systems will be required to both enable and accommodate the diverse, and highly capable, aircraft of the future. Many of these improvements will be integrally linked with advances in information technology. For example, the combination of satellite-based guidance and navigation systems and sensor/information technologies will enable the debut of "highways" in the sky. Essentially, these skyways would appear in the cockpit display of an aircraft as actual paths in the sky, and individual aircraft pilots would be able to choose their own flight paths within the boundaries of these paths, much as does today's automobile driver on the highway. Such a capability could be a major factor i revitalizing the general aviation aircraft market, approximating a personal transportation" concept for low-cost flight.

Other advances will include all-weather flight capabilities, a seamless country - to - country global air traffic management system, and the capability to operate autonomously in regions of the globe with undeveloped or underdeveloped air traffic systems -- again enabled by satellite-based guidance and navigation capabilities.

It is against the background of these and other potential advances in aeronautical science and technology, and associated infrastructure, that the Aeronautics Enterprise program is defined and planned. U.S. manufacturers and airline operators must be able to compete in these new, and technologically advanced markets, and the Aeronautics Enterprise will play a major role in ensuring that these and other advanced technologies and capabilities are developed.

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III. AERONAUTICS ENTERPRISE CHARTER AND MISSION

AERONAUTICS ENTERPRISE MISSION STATEMENT

To be the world leader in pioneering high-payoff, critical technologies with effective transfer of research and technology products to industry, the Department of Defense, and the Federal Aviation Administration for application to safe, superior, and environmentally-friendly U.S. civil and military aircraft, and for a safe and efficient National Aviation System.

We will aggressively pursue the identification, development, verification, transfer, application, and commercialization of aeronautics technologies to stimulate economic growth and to enhance U.S. competitiveness and world leadership in both aerospace and non-aerospace industries. In addition, we will ensure the continuing excellence of U.S. aeronautics for future generations by fostering and supporting multi-disciplinary education in elementary, secondary, and higher institutions of learning.

NASA carries out its aeronautics mission in partnership with the Federal Aviation Administration, the Department of Defense, industry, and academia. Our primary role lies in basic and applied research and technology development. In addition, through the operation of national aeronautical facilities, NASA is involved -- in close cooperation with industry, DOD, and FAA -- throughout the development process.

In 1915, Congress established the National Advisory Committee on Aeronautics, the forerunner of NASA's Aeronautics Enterprise, to "supervise and direct the scientific study of the problems of flight, with a view to their practical solution." For forty-three years, the NACA, by founding a series of national laboratories and by coordinating national investments in aeronautical research and technology, helped to establish an enduring national partnership -- composed of government, industry, and academia -- that propelled the United States into a leadership position in both civil and military aviation.

The NACA charter, and the successful government/industry/academic partnership, was validated and renewed by the National Aeronautics and Space Act of 1958, NASA's founding legislation. The Space Act and its amendments, among other objectives, call for NASA to:

- Improve the usefulness, performance, speed, safety, and efficiency of aeronautical vehicles;

- Establish long-range studies of the potential benefits to be gained from, the opportunities for, and the problems involved in the utilization of aeronautical activities for peaceful and scientific purposes;

- Preserve the role of the United States as a leader in aeronautical science and technology and in the application thereof; and

- Preserve the United States' preeminent position in aeronautics through research and technology development related to associated manufacturing processes.

In pursuing these goals, the NACA and NASA Aeronautics have returned large dividends on modest Federal investments. For example, as a result of NASA research in combustion, turbomachinery, lubrication, aerodynamics, acoustics, and materials and structures, airliners are 50 percent quieter, 25 percent more fuel efficient, and emit less than half the pollutants compared to twenty years ago. Today, NASA's Aeronautics Enterprise is challenged to play a major role in the development of high-risk, high-payoff aeronautical technologies for both civil and military applications.

An Appropriate Government Investment

Past accomplishments notwithstanding, in an era of reinventing government all departments and agencies must answer the question - Why is yours an appropriate expenditure of the taxpayers' dollars? In the case of aeronautics and the air transportation system, the answer is two-fold.

First, aviation industries and the air transportation system are critical to the economic and national security of the United States. The aeronautics industry generates almost $100 billion in annual revenues, accounts for almost 10 percent of U.S. manufactured exports, supports a transportation system that services the entire economy, and provides a key element of a technologically-sophisticated, and effective, national defense. Future competitiveness in these key areas is contingent upon new advances in technology.

Second, aeronautical research and technology is characterized by:

- A need for sophisticated -- and expensive -- research facilities, including wind tunnels, simulators, supercomputers, and research aircraft that are beyond the ability of individual companies to afford;

- A long, and costly, research and development cycle with paybacks often 10-15 years in the future, making it difficult for the private sector to justify major investments;

- The inability of the private sector to fully capture the benefits of investments in generic advanced technologies, again serving as a disincentive to research investments; and

- Required technology investments in support of various "public-good" objectives, including the safety, productivity, and environmental compatibility of the national air transportation system.

As summarized by the National Science and Technology Council's (NSTC) Interagency Coordinating Committee on Transportation Research and Development (CTRD), Since the public benefits of long-term research often can not be fully captured by private investors under these circumstances, federal research partnerships are essential for ensuring a continuous flow of innovation. These factors make it essential that the government continue to invest in the development and operation of aeronautical research and development facilities, and in areas of basic and applied research and technology where industry would otherwise underinvest.

The CTRD report affirms the need for specific investments in aeronautical research and technology, and has established the following priority and objective:

- Maintain world leadership in aircraft, engines, avionics, and air transportation system equipment for a sustainable, global aviation system.

The CTRD has further identified the need for:

- A validated technology base which will enable the commercial development of safe subsonic and high-speed civil transport aircraft that far surpass today's aircraft in affordability, efficiency, and environmental compatibility, as well as the development of a safer, more efficient, and more productive air traffic management system.

These policies and goals form a solid foundation for a continued Federal investment in aeronautics research, technology, and facilities.

The Aeronautics Enterprise Team

NASA's Aeronautics Enterprise is a key part of this national investment, providing

- Large-scale, national facilities in support of aeronautical research and development;

- Research in critical technology areas; and

- A skilled group of aeronautical researchers who are frequently called upon to help solve a variety of research challenges for industry and other government agencies.

The core of the Enterprise team is represented by the four Aeronautics Centers (see Figure 1):

Ames Research Center. Center of Excellence in Airspace System Operations, with lead roles in human factors research and air transportation management; and Center of Excellence in Information Systems, with lead roles in scientific computing, communications and networking, intelligent systems, and infrastructure technologies.

Dryden Flight Research Center. Center of Excellence in Flight Research, with lead roles in experimental aircraft, test bed research programs, and flight instrumentation and test technologies.

Langley Research Center. Center of Excellence in Airframe Systems, with lead roles in airborne systems, structures and materials, aerodynamics, mission and systems analysis, and crew station design and integration. Langley also has a lead role in hypersonic propulsion.

Lewis Research Center. Center of Excellence in Propulsion, with lead roles in subsonic and supersonic propulsion and propulsion support.

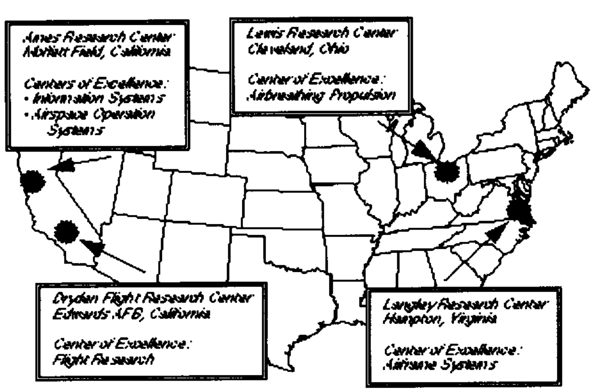

Figure 1. Aeronautics Enterprise Centers

The Aeronautics team, however, extends far beyond these four facilities. NASA research is aeronautics is conducted in conjunction with universities, airframe and engine manufacturers, and other government agencies. It is through the combination of all of these talents, utilizing contracts and cooperative programs with industry, cooperative programs with other government agencies, and grants and cooperative programs with universities -- in short, utilizing the "best of the best" from all sources -- that the Aeronautics Enterprise makes its contributions to industrial competitiveness, to economic growth, to national security, and to the effectiveness and efficiency of the national air transportation system.

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IV. CUSTOMERS AND ENVIRONMENTAL ASSESSMENTS

Customers - "entities that require NASA-developed technologies, facilities, and/or technical expertise to enhance the economic competitiveness, military security, and air transportation infrastructure of the United States."

Each of the Aeronautics Enterprise's products and services -- facilities, research, and world-class technical expertise -- is part of an aeronautical research and technology development "chain." As depicted in Figure 2, this chain typically begins with basic research, and then moves through successive stages of definition and maturity until specific technologies are inserted for use in specific aviation and related products. Although NASA's primary role is in the earlier stages of the chain -- research and technology typically characterized by high-technical risk, potentially broad application, and relatively lower investment levels -- the Enterprise is involved in subsequent stages, as well.

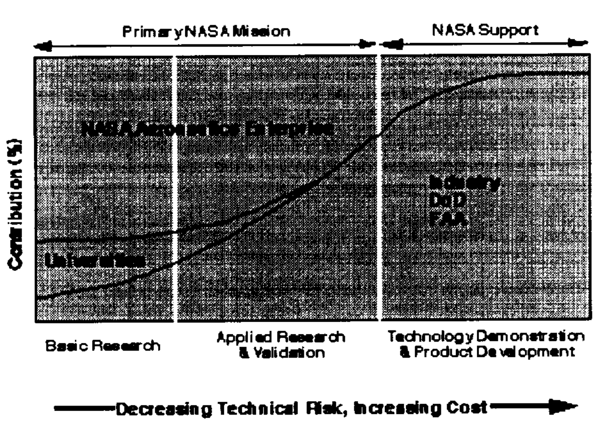

Figure 2. Roles and Relationships in the Technology Chain

In general, however, the Enterprise's customers are those entities which are involved in aircraft, engine, and sub-system product development (i.e., for commercial markets and/or for military aircraft) or in providing services to aircraft operators (i.e., air traffic control services).

Specifically, the Aeronautics Enterprise provides the following products and services to its major customer segments:

Aeronautics Industry

- Advanced technologies that (a) will enhance the economic value of current or future products; (b) are developed to the point where industry is able to assume the technical and market risk associated with further product development and application; and (c) are available at the right part of the product development cycle;

- Critical facilities required to support industry research and development programs; and

- State-of-the-art expertise to assist in resolving significant technical challenges.

Federal Aviation Administration

- Advanced technologies and concepts to support the maintenance of a safe, efficient, and environmentally-friendly air transportation infrastructure;

- Critical facilities required to support research and development programs; and

- State-of-the-art expertise to assist in resolving significant technical challenges.

Department of Defense

- Advanced technologies and concepts to develop revolutionary capabilities in support of future generations of military fixed- and rotary-wing aircraft; and

- State-of-the-art expertise and facilities to assist in resolving significant near-term technical challenges.

Academic Community

- Access to experimental, computational, and other facilities to support fundamental research and contract/grant activities; and

- Support for educational initiatives to foster the development of the next generation of scientists and engineers, as well as an educated public.

Non-Aeronautics Industries

- Access to NASA-developed technologies, facilities, and other products and services to enhance national economic competitiveness.

EXTERNAL ENVIRONMENTAL ASSESSMENT

As mentioned earlier, NASA's aeronautics customers play major roles in the economic growth and national security of the United States. In 1994 (a year of record low performance) the aerospace industry, primarily aeronautics, generated $112 billion in sales, over $38 billion in exports, and over $25 billion in positive balance of trade. Approximately one-third of the total defense budget historically goes toward military aviation, including fighters, bombers, rotorcraft, and support and supply aircraft and operations. And, in 1994, the national air transportation system, regulated and managed by the Department of Transportation and the Federal Aviation Administration, handled roughly half-a-billion passenger trips and 12 billion ton-miles of freight and express cargo.

Dynamic change is buffeting all of the Enterprise's customers. Although each customer segment is facing its own challenges, there are several factors which have severely affected the industry as a whole:

- Transition to a Post-Cold War Environment. The emergence of the United States as the sole military superpower has had a three-fold impact on the aviation industry. First, reductions in overall defense spending have translated into fewer sales, and perhaps more importantly less research and development spending, for domestic manufacturers. The Department of Defense estimates that internal industry research and development (IRAD) expenditures have dropped by 50 percent since the mid 1980's.

Second, investment priorities have shifted away from military applications and toward dual-use and commercial products, as well as toward export markets. Among other impacts, this shift has left the domestic rotorcraft industry -- which had emphasized military sales while losing ground to foreign competitors in the commercial marketplace -- dangerously exposed. Domestic rotorcraft sales have fallen from 1,366 units in 1980 to only 288 units in 1994, and the industry is facing consolidation among the four remaining manufacturers.

Third, future military requirements, including aircraft, will be placing increasing emphasis on affordability, complementing traditional performance goals.

- **Airline Industry Losses.** Commercial airline operators have been hard hit in recent years due to a combination of deregulation, rising labor costs, and a mature market within the United States. In all, scheduled U.S. airlines have lost almost $13 billion -- and 100,000 jobs -- in the last four years.

The impact of this situation on aircraft manufacturing has been both direct and substantial. In 1994, worldwide orders for large commercial jetliners hit a decade- long low. Approximately 260-270 new jets were ordered, down from 364 in orders in 1993 -- previously the worst year in a decade. These developments have reduced returns on investment for aircraft and engine manufacturers at the same time that escalating costs have increased the risk associated with the development and launch of new aircraft. In addition, new technologies are evaluated almost solelyfor their potential to reduce airline operating costs, as opposed to improve performance.

- **Foreign Competition.** During the same period in which domestic producers have been facing this "profit squeeze" between cost-conscious customers and escalating production costs, foreign competition, often subsidized by their host governments, has captured a large share of previously U.S. dominated markets. For example, U.S. manufacturers held 80 percent of the large commercial transport market in 1974, but only 68 percent in 1993. And in 1994, for the first time ever, Europe's Airbus Industrie consortium posted more new orders than did Boeing. Similar losses are working their way through the lower-tier supplier industries. Although subsequent trade negotiations have been addressing this situation, concerns still remain about future foreign support in aircraft development and production.

- Growing Challenges in the Air Transportation Infrastructure. The U.S. air transportation system continues to face growing congestion and delays. In 1994, air traffic control delays of at least 15 minutes totaled 688 per day and cost U.S. industry about $2.3 billion in additional fuel, labor, and related expenses. Approximately 23 major U.S. airports currently suffer severe congestion and delay problems, and more are expected in the future. In the growing Pacific Rim and South American markets, the lack of an adequate air traffic management infrastructure is a serious challenge to productivity and continued safety.

Effects of these and related trends are visible throughout the Enterprise's customer base. For example, the U.S. gas turbine engine industry, which supplies jet engines to the airframe manufacturers, has since 1990 experienced reductions in sales of 25-50 percent and in employment of 35-50 percent -- the equivalent of losing an entire major U.S. engine company. That same industry has also experienced over a $2 billion cumulative drop in research and development spending from 1990 to 1993. And, as large as those losses are, they pale beside the general aviation industry, where shipments have dropped from over 17,000 units in 1979 to 900 units in 1994.

In spite of these trends, the future offers promise as well as challenge for the aeronautics community. World-wide air travel, paced by growth in the Asia-Pacific market, is still forecast to grow by 5.2 percent per year through the year 2013, and air cargo is expected to triple during the same time frame. This growth, coupled with growth expected from replacing older, noisier, and less fuel-efficient jet aircraft with newer models, is predicted to require delivery of almost $1 trillion worth of new jet transports in the next 20 years.

To capture the benefits of this growth, domestic engine and airframe manufacturers in all industry segments will require access to high-risk, high-payoff research and technology efforts to address product cost, quality, and reliability, as well as the need for shortened product development cycles. Removing the "barriers to growth" represented by capacity and environmental constraints in the air transportation system will also require new technology. The U.S. air traffic system must keep pace with anticipated demand, and U.S. products equipped to operate in underdeveloped airspaces will enjoy a significant competitive advantage.

INTERNAL ENVIRONMENTAL ASSESSMENT

Internally, the Aeronautics Enterprise faces its own challenges and opportunities. The Enterprise has many strengths, including:

- An eighty-year history of successful aeronautical research and technology development in partnership with industry, academia, and other government agencies;

- A significant investment in world-class research facilities, including wind tunnels, supercomputers, and testbed aircraft;

- A highly-skilled and motivated workforce; anchored by world-class researchers in critical aeronautics disciplines; and

- Bipartisan recognition of the importance of

NASA's role in supporting the aviation and aeronautics industries.

Further, by virtue of the fact that technology solutions and services are required by all facets of the industry -- low-speed to high-speed, civil and military, product and process, and aircraft and airspace system -- the Enterprise has a unique perspective on the total aeronautical systems context. This broad perspective makes NASA a strong candidate for playing a leadership role in the identification and prioritization of Federal investment priorities.

The current environment also presents a number of challenges, including:

- Current and anticipated reductions in both civil service and contractor workforce may result in skill mix problems, as researchers in critical discipline areas can not be replaced;

- Continued downward pressure on the overall Enterprise budget threatens to erode basic research capabilities, potentially damaging the ability of the Enterprise to conduct future focused technology programs; and

- Current trends in both federal hiring and student career choices may contribute to a "drying up" of the pipeline of future aeronautical scientists and engineers. (For example, undergraduate enrollments in aerospace engineering have declined by 50 percent in the last six years, and graduate enrollment is beginning to decline.)

In addition, the Enterprise must continue to address the issue of aging aeronautical facilities -- in some cases lagging foreign facilities in capability and productivity. It was recognized in the 1980's that many of these national facilities, most between 30 and 40 years old, were seriously deteriorating and much less productive than more modern facilities. While the Wind Tunnel Revitalization Program, initiated in 1989, has ensured the continued reliable operation of these facilities for our customers, additional investments are required to improve the productivity of many facilities to a world-class level.

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V. STRATEGY AND RATIONALE

Aeronautics in the United States is at a critical juncture. Aviation-related industries face a range of challenges, as does the air transportation system. Twenty-first century competitiveness requires advanced technology solutions, both to compete in global markets and to remove the "barriers" to growth in those markets. NASA's Aeronautics Enterprise, as a provider of advanced technology solutions and research support to all facets of the aeronautics community, is in a unique position to address the future technology requirements of the nation as an integrated whole. At the same time, traditional drivers and providers of technology are all undergoing change: the industry and the defense department are reducing their investments in basic and applied technology, and the FAA is in the midst of significant organizational flux.

Given this environment, and given our charter to "preserve the role of the United States as a leader in aeronautical science and technology and in the application thereof," we have chosen to adopt an aggressive, high-payoff strategy. Our strategy, as part of a national partnership, is to aim for -- and achieve -- a national leadership position in the planning and conduct of the nation's aeronautical research and technology effort. This strategy has three basic components:

Shared Leadership in Determining National Priorities and Investments

The first component of this strategy is to step up to a more prominent role in determining our national aeronautical priorities and investments. Recently, NASA has been charged by the Office of Management and Budget to develop an integrated national strategy and priorities assessment for civil aeronautics. Using this opportunity as a starting point, we will work with our government, industry, and academic partners to:

- Develop a shared vision for U.S. aeronautics;

- Create a strong government-industry national partnership program for global aviation leadership, with NASA as a leader and integrator in planning and implementing a long-term U.S. aviation technology strategy;

- Leverage a strong NASA technology base as a source of advanced concepts and innovative technology, in an integrated product and process environment, to develop revolutionary national product and system capabilities; and

- Coordinate federal investments and foster greater civil-military interaction to ensure maximum impact and integration between public and private sector needs.

Being A Key Contributor to The National Partnership

The second component of a successful leadership strategy is to lead by example, by delivering on our commitments, by seeking innovative and cost-effective ways to do business, and by focusing on high-payoff research.

Delivering on our commitments means includes working toward increased:

- **Customer involvement**, actively involving our customers and partners in the identification of technology requirements and opportunities, in the development and execution of our research activities, and in assessing the level of satisfaction with the products and service that we provide;

- **Program measurement,** establishing metrics for both the day-to-day conduct of each of our research programs and for reporting to external customers and stakeholders; and

- **Program accountability**, ensuring that there are clear lines of authority in place for each of our program efforts.

Finding new ways of doing business is essential for making leadership affordable. We have already placed on stand-by, and in many cases closed, obsolete and lower priority facilities and aircraft, and have reduced and consolidated research support services. In addition, the Enterprise has embarked upon a major internal restructuring exercise, chartered to "provide a strategic advantage to NASA programs through the development of enabling infrastructure and support systems that are responsive to the needs of programs and customers and managed in a creative, business-like manner at the lowest possible cost." This effort will result in:

- A stronger linkage between programs and supporting infrastructure;

- Increased accountability by providing the ability to determine total program costs;

- Program and project manager participation in the determination of appropriate levels of support products and services;

- Innovation in management, service technologies, and cost reduction; including sharing, consolidation and privatization of services; and

- A mechanism by which senior Enterprise management can strategically plan and provide for the institutional capabilities required for future programs.

In addition, we will utilize strategic partnerships and alliances with customers and other research organizations to leverage critical resources and capabilities.

Focusing on high-payoff activities means:

- **Utilizing a systems approach**, ensuring that our research programs have the highest possible return on investment in a total aviation system, and indeed, total transportation system, context;

- **Pursuing high-impact, high visibility initiatives,** and recognizing that high reward often requires high risk; and

- **Rolling over lower priority programs** to provide funding for higher-priority research in a constrained budget environment.

Ensuring That Aeronautics Benefits All

The third component of our national leadership strategy is to ensure that federal investments in aeronautical research and technology benefit all of our stakeholders -- all Americans. To address this need we will:

- **Ensure diversity** in all our Enterprise activities by increasing the representation of women and minorities in our civil service workforce, and by encouraging our contractors to do the same. We will make diversity a business objective, attack the supply line aggressively, and move to build a supportive constituency from underrepresented communities.

- **Ensure inclusion** in the conduct of our research programs. We will use the "best of the best" from all sources -- small and disadvantaged businesses, women-owned firms, historically black colleges and universities, other minority educational institutions, large universities, large businesses -- to ensure the greatest possible return on investment for the taxpayer's dollar;

- **Support education** at all levels to ensure a continuing supply of qualified and motivated scientists and engineers; and

- **Communicate** to the public and involve the entire country in the benefits of aeronautical research and technology through educational and other outreach activities.

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VI. STRATEGIC PROGRAM GOALS AND OBJECTIVES

In order to ensure that Enterprise research and technology efforts are focused on high-priority, customer-driven requirements, the aeronautics program is planned and developed around six strategic "thrusts". Each of the six thrusts -- subsonic, high speed, high performance, hypersonics, critical disciplines, and national facilities -- represents a critical customer market segment or a research and technology product line. Within each thrust, high-payoff technology requirements and opportunities -- both nearer-term (i.e., 5-7 years) and longer-term (i.e., greater than 7 years) -- are identified in conjunction with a range of private- and public-sector customers, and research programs developed, budgeted, and implemented to address these technology challenges. Current strategic thrust goals and objectives are as follows:

Thrust #1. Subsonics Goal and Objectives

"Develop, by 2001, high-payoff technologies for a new generation of environmentally compatible, economic U.S. subsonic aircraft and a safe, highly productive global air transportation system."

Today's air transportation environment is a complex system, driven by a variety of elements including aircraft technologies, safety and environmental technologies, and the needs of airline operators and the airspace system. NASA's subsonic technology programs seek to integrate technological advances in all of these areas to improve the competitiveness of U.S. civil aircraft and the productivity of the air transportation system. The success of these efforts will be measured by how well NASA contributes to the capture of a larger share of the world market for civil aircraft by U.S. manufacturers and to the effectiveness and capacity of the national air transportation system. Program objectives include:

Aircraft Technologies

- **Integrated Wing** - Reduce drag by 30-40 percent leading to an 8-10 percent reduction in aircraft direct operating cost (DOC).

- **Advanced Propulsion** - Increase fuel efficiency by 8-10 percent through the application of high-temperature materials and high-efficiency concepts, leading to a 3-10 percent reduction in DOC.

- **Advanced Composite Wing** - Reduce weight by 50 percent and manufacturing cost by 25 percent, leading to a 6-10 percent reduction in DOC.

- **Fly-By-Light/Power-By-Wire** - Address risk reduction for cost, safety, and certification, leading to a 10 percent reduction in aircraft operating weight empty (OWE).

- **Short-Haul Aircraft/Civil Tiltrotor** - Eliminate the technology barriers to the introduction of a civil tiltrotor.

- **Short-Haul Aircraft/General Aviation** - Reduce costs by 25-40 percent in airframe manufacture and 50 percent in all-weather flight systems.

Airspace System Technologies

- **Cockpit/Air Traffic Control Integration** - Increase airport capacity by 10-15 percent while maintaining high levels of safety.

Environmental Technologies

- **Noise Reduction** - Reduce engine/airframe noise levels by 10 decibels by the year 2000.

- **Engine Emissions** - Reduce nitrogen oxide emissions up to 70 percent by the early 21st century.

Other Safety-Related Technologies

- **Aging Aircraft** - Develop commercially available non-destructive evaluation (NDE) techniques and an airframe residual strength prediction capability by 1997.

Thrust #2. High-Speed Goal and Objectives

"Ready, by 2005, the technology base for an economically viable and environmentally friendly high speed civil transport."

Long-range international travel, particularly travel related to rapidly expanding Pacific Rim commerce and trade centers, is the fastest growing sector of the projected air traffic market. Industry trade studies indicate that a substantial market for a high-speed civil transport (HSCT) -- a supersonic commercial aircraft -- exists to serve long-distance routes provided (1) acceptable environmental standards for airport noise and sonic boom levels can be met; (2) the projected fleet will have no harmful effects on the atmosphere; and (3) ticket prices will be less than 20 percent higher than corresponding next generation long-haul subsonic transport fares. Studies further indicate that successful U.S. leadership in this next-century market could mean a difference of $200 billion and 140,000 jobs for domestic aircraft manufacturers. The High Speed Research (HSR) Program is designed to address the technology requirements related to these barrier issues. Following a successful -- and joint -- technology effort, U.S. industry will be in a position to determine whether or not to invest in the development of an HSCT. Program objectives include:

Phase I. Resolve Environmental Concerns

- **Stratospheric Ozone** - Develop predictions of HSCT effects on atmospheric ozone; Verify ultra-low nitrogen-oxide (NOx) formation (5 grams NOx per kilogram of fuel burned) in practical engine combustor sector tests.

- **Airport Community Noise** - Verify capability to achieve FAR 36-Stage 3 noise rules through analytical combination of noise-reduction concept test results; nominally a 20 decibel reduction in aircraft sideline noise.

- **Sonic Boom** - Determine sonic boom reduction levels achievable with less than a 2 percent loss in aircraft aerodynamic performance (relative to a supersonic, over- water/subsonic, over-land baseline configuration).

Phase II. Develop Key Enabling Economic Viability Technologies

- **Airframe** - Demonstrate improved aerodynamic performance and integration leading to a 33 percent increase in range and a 50 percent reduction in noise take - off footprint; Develop improved airframe materials and structures that are 33 percent lighter and can sustain 350 degrees Fahrenheit for 60,000 hours.

- **Flight Deck Systems** - Develop the advanced systems and certification guidelines required for safe and efficient aircraft operations in the international airspace system; Incorporate synthetic vision, high-level information management, and integrated displays and controls into a next-generation cockpit.

- **Propulsion** - Develop technology for advanced high-efficiency, low environmental impact propulsion system components (including 5 grams NOx/kilogram fuel burned; cruise thrust coefficient of 0.98; and cruise pressure recovery of 0.93).

Thrust #3. High-Performance Aircraft Goal and Objectives

"Ready the technology options for new capabilities in high performance aircraft."

NASA's high performance aircraft program, conducted in close cooperation with the Department of Defense, provides technology options for revolutionary new concepts and capabilities in future high-performance fixed- and rotary-wing aircraft. Research is directed at high-payoff challenges, such as controlled flight at high angles-of-attack, that will ensure that U.S. pilots continue to fly the best planes in the world.

The high performance program also develops technology that helps improve the performance of the current generation of military and civil aircraft. The Enterprise is increasing its emphasis on dual-use technologies in this area, taking advantage of our long partnership with the DOD to exploit potential broad applications of technology developed primarily for military requirements. Program objectives include:

- Establish flight validated design and test methods, by 1996, to enable a 100 percent increase in aircraft usable maneuver envelope.

- Develop multi-axis thrust vectoring, by 1998, to double aircraft roll agility at stall while allowing 50 percent reductions in required airframe pitch and yaw stability levels.

- Establish validated integrated flight and propulsion controls design methods by 1999 to enable an 8 percent reduction in take-off gross weight (TOGW) for fighter aircraft and a 2 percent reduction in TOGW for advanced supersonic transports.

- Support and participate in the development of critical supersonic short-takeoff vertical landing (STOVL) technologies.

- Identify and pioneer high-leverage survivability technologies.

Thrust #4. Hypersonic Research Goal and Objectives

"Develop and demonstrate technologies for airbreathing hypersonic flight."

The hypersonic research program is an ongoing fundamental research and technology activity focused toward the development of technologies for hypersonic vehicles with potential for launch, cruise, and reentry applications. As a research and technology program, it stresses fundamental technical understanding of the controlling physical phenomena of hypersonic flight. The hypersonic research program stimulates the development of U.S. hypersonic research capabilities, and promotes industry, university, and international participation in hypersonic studies. As a natural progression of the Enterprise's subsonic and high-speed efforts, high-payoff research and technology development in hypersonics will help the United States maintain its lead in the world aerospace marketplace of the twenty-first century. Program objectives include:

- Address propulsion system optimization, actively-cooled propulsion structures, and variable geometry inlets.

- Conduct in-depth vehicle integration and optimization analyses of hypersonic vehicles to identify high-payoff future research priorities.

- Continue tests of the large-scale Concept Demonstration Engine, expanding the test matrix from Mach 7 simulated flight conditions (for scramjet power) to Mach 5 conditions for ramjet powered flight in FY1995 and FY1996.

- Perform a Mach 5 to 6 boundary-layer-transition flight experiment by piggybacking onto the first stage of a scheduled Pegasus satellite launch in late CY1995/CY1996.

- Conduct a Mach 6.5 ramjet-to-scramjet transition flight experiment using Russian hardware and flight facilities in early FY1997.

Thrust #5. Critical Disciplines Goal and Objectives

"Develop advanced concepts, physical understanding, and theoretical, experimental, and computational tools to enable advanced aerospace systems."

The Aeronautics Enterprise strongly supports basic research in technical disciplines important to aviation, including aerodynamics, materials and structures, human factors, and propulsion. Emphasis is placed on advancing the fundamental knowledge of physical phenomena critical to the performance of aerospace systems, and on efforts to identify and develop new concepts that promise revolutionary advances in given disciplines and/or aerospace capabilities. These higher-risk, longer-term research efforts offer a potential for high-payoff, and set the foundation for future vehicle/system-focused technology programs.

In addition, advances in computing and other information technologies are key to future aerospace competitiveness, offering accelerated development cycles, reduced vehicle development cost and risk, and full aerodynamic optimization of entire vehicle systems. The Aeronautics Enterprise hosts NASA's participation in the Federal High Performance Computing and Communications (HPCC) Program, an integrated effort focused on Grand Challenges in both computational aerosciences and earth and space sciences, and on advances in information infrastructure technology and applications. NASA's program brings together teams of computer and computational scientists to develop the necessary technologies unique to NASA missions, including applications algorithms and programs, systems software, peripherals, networking, and high performance computing software. NASA's HPCC Program, and other information systems-related efforts, help contribute to the vision of the NSTC's Committee in Information and Communications to "accelerate the evolution of existing technology and nurture innovation that will enable universal, accessible, affordable application of information technology to ensure America's economic and national security in the 21st century."

Critical disciplines program objectives include:

- Conduct experimental and analytical disciplinary research in fluids, propulsion, and power; materials and structures; controls, guidance, and human factors; and flight systems to:

    - Validate analytical methods for fluids, structures, and human factors to increase design reliability by 50 percent;

    - Develop advanced lightweight, high-temperature materials for 30 percent improvement in aircraft efficiency;

    - Reduce pilot error by 50 percent through aircraft crew performance and workload management strategies.

- Develop multidisciplinary analysis and design methodologies and verify during validation of advanced concepts:

    - Reduce aircraft noise to background levels through strategies for active reduction of noise;

    - Develop methods to reduce product design and development times by up to 50 percent.

- Develop test techniques, measurement technologies, and facility concepts to enable code validation and advanced concepts evaluation, including:

    - Non-intrusive flow diagnostics and fiber optic sensors for multi-dimensional measurement;

    - Innovative in-flight flow measurements with accuracies equivalent to wind tunnel measurements.

- Accelerate the development, application, and transfer of high-performance computing technologies to meet the engineering and science needs of the U.S. aeronautics community:

    - Develop and apply a 1,000 fold increase in computing capability and a 100 fold increase in communications capability;

- Provide supercomputer capability at workstation prices;

- Provide to the U.S. aerospace community, by 2003, an operational computing system that can simulate an entire aerospace vehicle within a computing time of from one to several hours.

Thrust #6. National Facilities Goal and Objectives

"Develop, maintain, and operate critical national facilities for aeronautical research and for support of industry, the FAA, DOD, and other NASA programs."

NASA's major aeronautical facilities include wind tunnels, propulsion facilities, testbeds, simulators, structural test facilities, flight research facilities, and laboratories at the Ames, Langley, and Lewis Research Centers and the Dryden Flight Research Center. These facilities, combined with the technical expertise of co-located laboratory personnel, are national assets supporting U.S. aeronautical research and technology and aircraft development. Program objectives include:

- Upgrade the productivity and capability of existing facilities, and construct new facilities as required:

    - Modernize the Ames Research Center's Unitary Plan Wind Tunnel Complex, providing new automatic tunnel and model support controls for tunnel auxiliaries;

    - Modernize the Langley Research Center's Low Turbulence Pressure Tunnel to enhance productivity in the testing of advanced high-lift systems by industry users;

    - Modify the Lewis Research Center's Icing Tunnel to keep the tunnel predictively operational and to improve productivity by increasing available test time by 20 percent;

    - Modernize the 40x80 Foot Wind Tunnel at Ames, part of the National Full-Scale Aerodynamic Complex, to improve productivity and reliability;

    - Upgrade the 14x22 Foot Subsonic Wind Tunnel at Langley to automate facility flow parameter control and model support control systems; and

- Construct a High Speed-Low Disturbance tunnel at Langley to support design developments for future high speed aircraft, including supersonic laminar flow control.

- Provide flight research testbed aircraft and support facilities for the discovery, investigation, and demonstration of advanced aeronautical concepts, including:

  - Develop the F-18 Systems Research Aircraft capability;

  - Develop the F-15B Aero Testbed capability;

  - Create an unpiloted flight development and operations capability.

Future Directions

In recognition of the dynamic environment in which its customers operate, the Aeronautics Enterprise must continually refine its research and technology program to ensure alignment with changing customer requirements. The Enterprise will, therefore, continue to rollover lower-priority program elements to fund higher-priority new efforts, and to advocate new national capabilities in aeronautical research and supporting facilities. Some of these areas that will receive increased emphasis include:

Integrated Product/Process Technologies. Current and future commercial and military aircraft requirements are driven by the need for increased affordability, improved quality and performance, and faster time-to-market. Meeting these requirements requires:

- Reducing design, development, and production cycle time and costs;

- Developing affordable manufacturing processes and technologies;

- Integrating products and processes; and

- Improving operations, reliability, and maintenance performance.

Numerous studies, for example the National Research Council's recent report on High Stakes Aviation, have called upon government and industry to work together to achieve quantum improvements in the development and application of process as well as product technologies, and to place a high priority on manufacturing and design processes. Advances in design and process technologies, coupled with an integrated design and test environment, will result in a 50 percent reduction in design and manufacturing cycle time, increasing the competitive edge for U.S. civil and military aircraft and engines. Specific areas of emphasis will include physics-based manufacturing and materials process modeling; materials and manufacturing cost modeling; affordable manufacturing technologies; critical part validation; integration of product/process technologies; and factory-floor level process modeling.

Advanced Air Traffic Technologies. NASA's advanced subsonic research efforts are addressing high-priority, nearer-term (i.e., 5-7 year) requirements associated with terminal area productivity, aircraft/air traffic control integration, collision avoidance and other issues affecting the safety and productivity of the nation's existing air transportation system. Longer-term, however, advanced technologies offer the promise of an entirely new air transportation system -- based on satellites -- that would both revolutionize the capability and capacity of the U.S. aviation system and provide new concepts for aircraft operating in countries with developing air transportation systems. NASA will continue to work closely with industry and the Federal Aviation Administration to identify potential concepts for new national systems, offering:

- Procedures for efficient mixing of transports, general aviation aircraft, commuter, and business aircraft, as well as non-conventional aircraft such as civil tiltrotors and high-speed civil transports

- Efficient, operator-selected routes (known as "free-flight") to slash operating costs; and

- Technology for minimum weather-related delays.

Success in these areas would lead to a significantly increased market for U.S. aircraft and air traffic system technologies.

National Wind Tunnel Complex (NWTC). As mentioned earlier, many of NASA's national wind tunnel facilities are over 30 years old. In Europe, however, six new government-funded tunnels have been built in the last 15 years, and offer superior capabilities compared to their older U.S. counterparts. In fact, the newest U.S. aircraft, the Boeing 777, made extensive use of these foreign facilities. In particular, a recently-completed National Facility Study examined future aeronautical facility requirements, and determined that the U.S. lacked the world-class development tunnels required to provide U.S. industry with a competitive advantage. Substantial improvements in facility capability, including higher Reynolds numbers (i.e., more accurate simulation of an aircraft in flight), increased productivity, and lower cost are required. Existing government and commercial facilities are inadequate, and upgrading existing facilities would not fully meet the requirements, the study concluded. NASA is working with industry, therefore, to develop two new high-productivity, high Reynolds number wind tunnels -- one subsonic and one transonic -- to respond to future industry development requirements.

Information Technologies. As the information revolution unfolds, information and communications technologies will enable dramatic transformations in our nation's economy, defense, and society. Further advances in information systems technologies underlie advances in all areas of aeronautical research and technology, and particularly the future directions areas outlined above. For example, with respect to advanced design and manufacturing process, synergism between numeric and symbolic computing will lead to design and analysis methods with greater capabilities and ease-of-use; advanced interface methods will assist in the use of complex analytical models and tools within industry; and advanced simulation, software engineering, database, and network techniques will be used to fully integrate computer-based design and manufacturing tools.

With respect to future air transportation systems, interacting intelligent systems in the aircraft cockpit will enhance aircraft safety and performance by improving the ability of pilots to make time-critical and complex decisions; knowledge in both numeric and symbolic computing methods will help provide the most robust and adaptive air traffic control system possible; and advances in networking technology will ensure real-time communication among ground and air-based pieces of the overall air transportation system.

Future experimental facility capabilities will also be enhanced by the application of information technologies. Advances in high performance computing, networking, and symbolic computing methods will combine to enable remote-users full access to many capabilities that now require a physical presence.

Basic Research Efforts. The Aeronautics Enterprise must continue to support the basic research capabilities that are the foundation for future advances in aeronautical technology. These capabilities must include the exploration, verification, and acceleration of technologies through world-class research programs and facilities. In addition, basic research efforts need to address advances in research methodologies, including instrumentation, computational tools, and experimental facilities, to enable future programs to deliver "more bang for the buck." This longer-term agenda must be geared toward higher-risk, highest-payoff technologies; such programs must also, however, be structured so as to be responsive to customers and to return benefits in the near-term, as well.

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VII. KEY ASSUMPTIONS

The strategy outlined above, as well as the more detailed strategic program goals and objectives, are based upon a certain set of assumptions about the external and internal environments in which the Aeronautics Enterprise operates. Should these factors change, a major reexamination of parts or all of the Enterprise strategy would be required. These assumptions include:

- Domestic/international air transportation needs will be met primarily by large subsonic transport aircraft.

- Continued congestion and environmental concerns regarding the National Airspace System, if left unaddressed, will constrain future market growth.

- Subsidized foreign industry and airline industry operating conditions will continue to place significant cost pressure on U.S. manufacturers and products.

- Phase I of the High Speed Research program will successfully address the critical barrier environmental issues associated with the eventual industry development of a high-speed civil transport (HSCT).

- The long-distance market will support a fleet of over 500 HSCT's shortly after the year 2005.

- U.S. industry will continue to invest its own funds in broad support of NASA's program.

- Military research expenditures and requirements will continue to hold steady or decline.

- U.S. industry will continue to require more capable and more productive development facilities (i.e., wind tunnels).

- The Administration/nation will continue to support investments in aeronautical research and technology.

In addition, long-term success of the Enterprise strategy and program goals is contingent upon the ability to:

- Meet current and future program commitments -- on-time and on-budget;

- Sustain a vital, longer-term focused research capability; and

- Develop next-generation scientists and engineers.

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VIII. IMPLEMENTATION STRATEGIES AND PRINCIPLES

In the conduct of its programs, the Aeronautics Enterprise will:

Ensure Relevance to Customers by involving the customer in the identification, development, and execution of programs to ensure that programs reflect current market realities and customer priorities. Assessments of relative technology value will be confirmed with an appropriate range of industry customers, and program priorities and progress will be periodically reviewed by external advisory committees. In addition, customer cost-sharing will be used as a metric in gauging relative program priorities among the Enterprise customer base. Peer review will also be utilized as a mechanism for obtaining external inputs and for selecting potential research directions.

Maintain a Balanced Program. In order to ensure that the Enterprise maintains the flexibility to respond rapidly to changing national requirements, priority will be given to program balance. Balance, defined roughly as "the right shares, not equal shares," will be maintained in a variety of dimensions, including by customer segment, by near-term/far-term research, by discipline, by in-house versus contract research, and by facility capability (i.e., analytical, wind tunnel, simulation and flight research). Core capability in the highest-priority areas will be identified and maintained.

Make the University Community a Full Partner. The university community is a vital component of the national aeronautics partnership, both as a source of research and innovative ideas in support of NASA programs, and as a source of qualified and motivated scientists and engineers for industry and other government agencies. The Aeronautics Enterprise will strive to strengthen its partnership with the university community by developing a clear role for that community within the Enterprise; by building a visible, accessible communications link between NASA and the universities; by reducing the administrative burden and improving the cost performance associated with university activities; and by redirecting existing agency activities to be more relevant to the needs of the Aeronautics Enterprise.

Exercise Responsible Stewardship of National Facilities. The Enterprise will continue to serve as a developer and operator of critical national aeronautical research and development facilities. Facility capability and access by Enterprise customers will be emphasized; reimbursement for services will be applied where appropriate.

Utilize Strategic Alliances. In order to leverage human and fiscal resources, the Enterprise will enter into various forms of partnerships, including cooperative programs, joint sponsored research agreements, and joint programs. Such use of cooperative programs will also ensure relevance to the customer and enhance technology transfer.

Emphasize Commitment to People. The Enterprise recognizes that the members of the Enterprise team are our "number one" asset. A high-priority will be placed on training, development, and employee empowerment and involvement. As detailed earlier in the Plan, particular emphasis will be placed on diversity and inclusion in all Enterprise activities.

Increase Measurement and Accountability. All Enterprise efforts will be subject to both output and outcome metrics. Program plans will identify clean lines of management responsibility and accountability, and will include detailed milestones and success criteria, as well as strategies for utilizing cost sharing and maximizing technology transfer. We will emphasize the use of program performance, schedule, and cost metrics to measure and evaluate progress on all program efforts. Customer service standards will be developed and applied, and periodic customer surveys will be conducted to gauge the level of customer satisfaction with the Enterprise's products and services.

Emphasize Technology Transfer. The Aeronautic Enterprise has long recognized the importance of ensuring that our customers actually use the products that we develop. The Enterprise will continue to emphasize technology transfer to the aerospace community through joint program planning and execution, and to all U.S. industry through proactive commercial technology utilization outreach efforts. The Enterprise will also continue to protect sensitive research and technology as appropriate.

Pursue Synergy with Other NASA Enterprises. The Aeronautics Enterprise shares research facilities, technologies, program objectives, and customers with the other four NASA Strategic Enterprises. Examples of these interactions include:

- **Space Technology Enterprise**
    - Commonality of basic research efforts in several aerospace disciplines
    - Shared research and institutional facilities
    - Coordination and implementation of technology transfer efforts
- **Space Science Enterprise**
    - High Performance Computing and Communication technologies

- Development of sensors and sensor technologies

- Development and operation of science platforms (e.g., aircraft)

- Mission To Planet Earth Enterprise

- Environmental impact assessments (e.g., HSCT on stratospheric ozone; AST work on noise and emissions)

- Development and use of remotely-piloted vehicles and other platforms and sensors for atmospheric studies

- High Performance Computing and Communication technologies

- Human Exploration and Development of Space Enterprise

- Development of trans-atmospheric vehicle/hypersonic vehicle technologies

- Crew performance/human factors research

- Facilities usage (e.g., NAS, Dryden Flight Research Center)

- High Performance Computing and Communication technologies

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IX. SUMMARY/CONCLUSION

As the United States prepares to enter the twenty-first century, we must ensure that we as a nation are making the technology investments that will keep the our country at the forefront in economic competitiveness, national defense, and quality of life. NASA's investments in aeronautical research and technology are direct investments in our future, and we are committed to working with our stakeholders, our customers, our suppliers, and our partners to make that future a reality.

This plan has laid out our strategy and goals for achieving national leadership in aeronautics. As we work with the nation to develop a shared vision for U.S. aviation, and as industry and other dynamics continue to unfold, we will ensure that this plan becomes a "living document", serving as a guide for setting future directions and as a tool for communicating our intent to our many constituencies. Together, we can both achieve aeronautical leadership for the United States and ensure that the fruits of that leadership are shared by all.

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If you have questions or comments about this document, or wish to obtain copies of the Aeronautics Strategic Enterprise Plan, please contact:

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